The results also show that the radiolocation and messaging capacities required are much larger than the total capacities of any currently deployed radiolocation or radio-data messaging systems. For example, estimates based on this latest data from the TransTech Conference suggest that on a per-million population basis, during the typically bi-daily 3-hour traffic peaks (the rush hours), about 170 position fixes per second or about 620,000 position fixes per hour would be required to get a high quality estimate of traffic conditions. (Assumed here is the need for an average three location and velocity estimates per IVHS-active vehicle mile.) This translates to about a thousand position fixes per second across the whole of the Washington-Baltimore Metroplex.

The addition of traveler-information functions to an AVM system make the total capacity requirements significantly larger. There are also other uses. Table 4 reflects estimates that include the IVHS data requirements of public transit (busses) and safety (police & ambulance/rescue), commercial, government and business fleets and individual automobile drivers. The estimates do not include data-base access by public safety operations.

With only moderate penetration of IVHS capability into this part of the market (3% of individual vehicle-owners, 10% of all fleet operators, and most of the safety and transit operators), Table 4 shows that the data requirements of traveler information systems are significant, roughly equaling that required by IVHS traffic monitoring. With modest market penetration, therefore, the capacity required to meet the demand for radiolocation and messaging is large. The approximately equivalent data capacity would be about 70,000 bits per second, delivered in short messages.

Because the ARRAY™ network utilizes the same broad-band signal to carry both the data message and the radiolocation function, it achieves significant gains in system capacity over other approaches. A particularly significant advantage is the support of a high data rate. Other techniques contributing to ARRAY™'s high throughput include its contemplated use of a very wide bandwidth (up to 26 MHz as explained in Pinpoint's earlier submissions in this proceeding) and frequency reuse in multiple coordinated base-station clusters in a given city.[2]

Other vehicle location approaches, for example, those which segregate the position fixing and communications elements, require twice as much system capacity to achieve the same throughput.[3] For example, GPS might be the vehicle location

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[2] ARRAY™ forms a virtual, rather than physical, cluster around each ARRAY-equipped vehicle. Central coordination allow co-existence of multiple clusters in a single metroplex.

[3] Vehicle location is never performed alone, but as a part of a larger, typically integrated solution, which usually involves some communications components, as required for management, control or support functions of the vehicle being located. In contrast, single-function system, (e.g., vehicle location alone) are sub-optimal solutions, because other, often overlapping, systems are then needed to fill out the full mobile resource solution requirements.

technology and a Mobitex or ARDIS system might be used for carrying the vehicle locations data and other messaging. The data capacity requirement to achieve Pinpoint's level of performance would be nearly twice as large, because about a half of the capacity would be needed for radiolocation only. Transmitting the location solution from the vehicle would require approximately the same amount.

Other, currently deployed, "stand alone" systems are clearly deficient for IVHS. A technology like Lo-Jack, a direction-finding tracking technology designed for stolen vehicle recovery (requiring a specially equipped tracking vehicle to physically pursue a beacon transmitter on the vehicle being located), is a low-volume system wholly unsuited to meet the multi-faceted requirements of IVHS, although it apparently works well for its designed purpose.

Hyperbolic multilateration technologies are philosophically suited to the IVHS tasks. They provide the vehicle's position at the location where it is used -- remote from the vehicle.[4] However, some implementations of hyperbolic multilateration systems, such as those of Teletrac and METS/MobileVision,[5] fall

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[4] Stand-alone vehicle location systems, such as GPS, require a second communications system to transmit the location information back to the central location where it is used.

[5] The reported 20 fixes per second capacity of the 2 MHz QuickTrack system utilized by Southwestern Bell Mobile Systems is even smaller.

far short of the dual capacity requirements of major metropolitan areas:

First, the maximum position fixing rates for both systems are between 35 and 100 position fixes per second, using 8 MHz throughout a given geographic market. Because they do not reuse spectrum, their position-fixing rate is fixed, regardless of the size of the metropolitan coverage area at issue. Using all the system's capacity for traffic monitoring barely satisfies the needs of a small metropolitan area (less than half a million population).

Second, if all of the narrowband 250 kHz forward-link bandwidth of these two systems were applied to data communications, the aggregate throughput would be about 60,000 bps.[6] This assumes no position-fixing whatsoever, and is lower than the minimum data requirements for IVHS in a moderately-sized market, as discussed earlier.

Moreover, narrowband data radios with this level of performance are only now becoming available, but at the very high cost (in relation to the target market's cost expectations) of about $2,000. This cost will likely inhibit rapid acceptance by the IVHS target market.

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[6] The forward-links were modeled as twenty 12.5 kHz-wide data channels capable of a user throughput of 5,000 bps, with a 60% overall packet-data protocol efficiency for the short-duration transmission data and radio-link protocols.

The level of capacity exhibited by Teletrac and METS suggest that their systems were designed (and, in the case of Teletrac, initially deployed) to satisfy narrowly defined market applications like stolen vehicle recovery. Unlike ARRAY™, these systems were not designed to achieve the capacity needed for applicability to a broad range of traffic and mobile resource management applications that span over many product markets, as typified by the many differing requirements embraced within the IVHS initiatives of the Intelligent Vehicle-Highway Systems Act of 1991 (*e.g.*, advanced traffic management, enhanced traveler information, commercial vehicle operations, and advanced public transportation systems).

At best, the technologies of Teletrac and METS are only marginally capable of satisfying the early needs of IVHS (at 2% to 3% penetration in a moderate market), and then only if their total capacity were dedicated to IVHS functions. However, as the IVHS market matures, the benefits of IVHS are more widely appreciated, equipment and service costs continue to fall, and the market expands, the systems of Teletrac and METS, as publicly described, will be unable to keep pace with the requirements in a moderately sized city. Even before IVHS has had the opportunity to reach threshold market penetration in a million-plus market (*e.g.*, Orlando or Louisville), their maximum capacity will already have become saturated.[7]

In comparison, a well designed hyperbolic multilateration system, such as the ARRAY™ system currently being tested in Washington, D.C., avoids these capacity limits. Multifunction waveforms combine position location and data transfer functions. Wider bandwidths and higher powered mobile transceivers dramatically increase the throughput while reducing the sensitivity to interference. Dynamic clustering allows frequency reuse within a metroplex. <u>A WELL DESIGNED HYPERBOLIC MULTILATERATION SYSTEM PROVIDES THE CAPACITY NEEDED FOR A MATURE IVHS IN A MAJOR METROPLEX</u>.

B. Results from the ARRAY™ Experimental System Confirm Its Suitability for IVHS and the Feasibility of Wide-Area System Sharing

Pinpoint has deployed an experimental radiolocation and messaging system in the Washington, D.C., area. The system currently consists of four base stations, a network control center, multiple host applications, and three mobiles. The purpose of the system is to confirm predicted performance of Pinpoint's proprietary radiolocation and messaging technology, to

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[7] These facts suggest why Teletrac's economic models must fail. By failing to acknowledge the full range of AVM applications for IVHS, Teletrac postulates a much smaller market than exists and chooses a bandwidth limit and system parameters to match. Pinpoint, in contrast, seeks to maximize capacity through larger authorized bandwidth, thereby making competitive sharing by a reasonably large number of high-capacity systems a viable option.

gather data on its performance, to validate the design predictions for national system buildout, and to explore alternative software and hardware approaches to the implementation of various network functions. Photographs of the system are attached hereto.

Results from Pinpoint's experimental system to date have demonstrated that the ARRAY™ system, like the Teletrac system, operates close to the Cramér-Rao bound. However, it is critically important to note that the bound does not illustrate, in itself, the character or limits of a system. The Cramér-Rao bound only illustrates the relative tradeoffs of system design parameters, such as bandwidth, power, and position-fixing time. For example, the design objectives of the ARRAY™ system are significantly different from those chosen for the Teletrac system, but both operate close to the Cramér-Rao bound. Teletrac's approach is a low-power approach, to the detriment of the position fixing rate. In contrast, ARRAY™'s position-fixing throughput was a critical design parameter, since it directly affected the economic viability of the system to meet IVHS applications. Throughput affects both network revenue generation and the cost of service to the user.

Another central performance criterion for the ARRAY™ system was reliable operation within the predicted noise environment of the 902-928 MHz AVM band. Pinpoint recognized the need to share the band with co-primary local area systems, as well as Part 15 users and amateur operations despite their secondary status. ARRAY™'s high-position fixing rate therefore required a relatively high-power approach, given the interference noise level expected in the AVM band.

The experimental ARRAY™ system is designed as a time-difference-of-arrival, hyperbolic multilateration, radiolocation system that carries high-speed two-way data in its radar-like, spread-spectrum ranging pulses. It uses multifunction pulses to simultaneously pass data in the radiolocating protocol and to improve the radiolocation resolution of any particular time-of-arrival estimate at the base stations.

With its experimental 16 MHz bandwidth system, Pinpoint achieves randomly-addressed mobile-unit position fixes in less than 1020 microseconds per fix. The Cramér-Rao bound within which this experimental system is working has a sigma of 2.4 nanoseconds. A protocol feature halves the time per fix when performing fixes on sets of vehicles that have been assigned to the same group. The line-of-sight ranging accuracy of ARRAY™ is less than five feet as confirmed in the field by laser range finders. This is within twice the design Cramér-Rao bound.

While achieving position fixes, the network control center is also obtaining a 3 byte "status message" from each vehicle being located. In addition, the system can tack packet messages onto the position-fixing pulses, with each additional packet occupying the same duration as a complete position fix, *i.e.*

about 1020 microseconds per packet of 24 bytes. The effective raw data rate obtained in the experimental system is thus about 185,000 bps.[8]

Operation of the 16 MHz bandwidth experimental system confirmed that this time-for-a-position-fix will result in a projected throughput rate of more than 1,500 randomly addressed, and 3,000 group addressed vehicular position fixes per second near a local cluster in a commercial system based on an 8 MHz authorized bandwidth, when operating with a Cramér-Rao bound of 4.75 nanoseconds and a two dB higher worst-case IF s/n ratio of -8 dB. The predicted effective raw data rate accompanying the position fixing in such a commercial system in the 8 MHz bandwidth would be 364,000 bps.

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[8] This data rate is presently limited by a target-cost constraint for the experimental system. The practical maximum throughput that can be achieved by the data signalling approach used in the ARRAY™ system is not constrained by technical issues, but rather by market target cost tradeoffs. Raw data rates near a megabyte per second can economically be achieved in a system bandwidth of 8 MHz, while simultaneously performing up to 2,500 position fixes per second locally, if somewhat higher power levels were used.

C. Measured Time-Synchronization Overheads, "Time-Slicing" and Competition

The synchronization airtime overhead for Pinpoint's experimental system is less than 0.17%. The equivalent timebase synchronization overhead for a fully-functional commercial system is projected to be less than one percent. A spread sheet showing the effect of such low overheads on the "waste" of airtime by sharing operations is shown in Table 5.

While this presentation adheres to the principles illustrated by Richard Schmalensee in Appendix 4 of Teletrac's comments, the numbers derived from Pinpoint's results undermine his conclusions. Even with a relatively large number of market participants, the synchronization overhead "costs" of sharing are moderate. The alternative is a duopoly offering restricted consumer choice and virtually no incentives for innovation. Such an approach would be inconsistent with the objectives identified by the FCC in the NPRM.

Teletrac's assertion that competition will lead to the "destruction" of the band's usefulness is incorrect. With the proposed time-sharing of the band, and with entry limited to genuine operators with real, demonstrable technologies and systems, and with strict assignment/transfer rules and construction deadlines, entry into the band will be self limiting. There will be little to gain by speculators. Only those with sufficiently high-performance technologies to viably enter the market will be able to survive, and those with marginal (or no) performance will be eliminated by the natural action of the market.

Pinpoint's experiment has also shown the feasibility of time-division sharing between wide-area systems positing a simple 50%-on, 50%-off scheme. Central to the test was synchronizing the ARRAY™ system for time-slice operation with reference to a standard time signal. This has been achieved without incurring any additional time-synchronization airtime overhead. Signals from the time reference interrupt the control processor in the master base station at regular intervals. Software then initializes the ARRAY™ network's master clock to restart near the interrupt. Because the activity is local and software-controlled, no additional airtime is consumed over that amount otherwise required for the remote base station synchronization/calibration functions.[9] Therefore, Pinpoint's system demonstrates that not only is simple time sharing of the band possible, it is possible without incurring the "tremendous waste of spectrum" predicted by other commenters.

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[9] The philosophical design underpinnings of the airtime scheduling approach used by the system is such that extending the time-sharing to more flexible schemes that make dynamic sharing of the band possible can be accomplished with manageable levels of cooperation between sharing participants.

D. Coexistence of Part 15 and Wide-Area Predicted Effects of Pinpoint's High-Powered, LMS is Practical.

Interference modelling and some field measurements have led Pinpoint to expect that some mutual interference is theoretically possible between wide-area LMS systems and Part 15 devices. In general, however, coexistence in the band is practical. The power for wide-area systems should not be constrained as suggested in the NPRM, and the more realistic power limits proposed by Pinpoint should be adopted. Generally, the performance of Part 15 devices will be less affected than the wide-area systems.[10] This is primarily the case because of the short-range nature of the Part 15 devices (up to a few thousand feet), whereas, by definition, the wide-area systems are working over significantly larger distances (1 to 10 miles).

As an initial matter, it should be noted that the level of interference caused by vehicular transmissions will be insignificant. A given vehicle will transmit very infrequently (once per second maximum, with less than 1% duty cycle, and usually less than once per few minutes to less than once per few hours). Base stations, however, could transmit with a randomly varying duty cycle, up to a maximum of about 30% for short periods consisting of randomly spaced short bursts (lasting from

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[10] The maximum power for a broadband forward link proposed by Pinpoint (i.e. 625 watts/MHz spread over at least 2 MHz up to 5 kw) is consistent with (and somewhat less than) that which can be authorized under Section 90.239 today (e.g. 1 kw into a 10 dB gain antenna).

300 microseconds to 15 milliseconds). These transmissions are not continuous nor predictable, except for synchronization transmissions which occupy less than 1% of the base station's actual operation, as discussed above.

In general, the low-power (*i.e.* less than 100 milliwatt output power) Part 15 devices will be least affected, since they are generally narrowband systems. Interference by a low duty cycle, intermittent, broadband "jammer," as presented by a wide-area AVM system should not be a major concern. The natural immunity of narrowband systems to broad-band interference protects these devices, and they will enjoy most of their previous operational characteristics.

A simple analysis of communication range prediction shows that Part 15 devices should not find the ARRAY™ system a major-interference concern. Assume a 100 milliwatt output (+20dBm), with 0 dB gain antenna, and a 10 kHz voice channel bandwidth on the Part 15 device, and a 10 MHz wide spread spectrum signal from Pinpoint's system. In these circumstances, a 30 dB reduction of ARRAY™'s interfering signal due to selectivity should occur. Due to the narrow horizontal beam width and elevation of the ARRAY™ base station transmitter's antenna, the ground-level interference signal due to the ARRAY™ transmission has a peak level in the range of about -50 to -60 dBm in a 0 dB gain antenna throughout the first half-mile range, the area of interest here. If the required IF s/n margin for adequate voice operation on the Part

15 device was 8 dB (giving about 12 SINAD using narrow-band FM), then the allowable path loss for the Part 15 device could be +20+30--55-8 = 97 dB. Assuming that the path loss is due to free-space propagation yields a communication range of about a mile. Allowing for an additional 15 dB signal attenuation from building penetration, a 1000 foot communication range could be expected in the presence of Pinpoint's system.

The situation for wideband Part 15 devices is, however, not as easy to consider, due to the large number of variation in design and trade-off choices available to spread spectrum designers. Narrowband, frequency-hopping devices should enjoy performance similar to that outlined above. Broad-band, direct-sequence devices, or broad-band frequency-hopping devices are more problematic to analyze due to the wide latitude in the systems termed "broad-band". In general, broad-band devices will intercept more of the jamming energy from a wide-band AVM system, and will generally only have moderate processing gains. For an illustration consider the following example:

A broad-band, direct sequence device uses a 4 MHz IF bandwidth for a wide-area data reticulation scheme. The device uses a 1K chip sequence, yielding about 30 dB processing gain, and the detector margin needed for adequate BER is 10 dB. The transmitter uses a full 1 watt power output and a 6 dBi gain antenna (+36dBm EIRP). It operates in a jamming field strength producing a -60 dBm signal at its receiver antenna. The permissible path loss under these conditions is +36+30-(-60)-10 = 116 dB. Assuming path loss that is part way between free space and UHF land-mobile propagation models, these assumptions would yield a communication range of between 2,000 and 4,000 feet in the presence of an ARRAY™ signal.

The very dispersed nature of the radiolocation network base stations would indicate that the level of interference predicted above would tend to be worst-case, since the areas most affected would only be a small proportion of the whole coverage area.[11] Furthermore, in the typically five-to-eight mile spacing between these interference areas, the overall interference levels will be significantly smaller.

Although the above examples do not exhaust the possible interference scenarios, they do support an important conclusion. Specifically, while some mutual interference between wide-area AVM systems and some Part 15 devices will occur, the magnitude of the interference on a system level should be manageable for both users.

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[11] The ratios of the total Part 15 coverage area to the areas in which interference is caused by LMS base stations would typically be between about 5 and 10. Thus, the interference free area would be 5 to 10 times as large as that within which interference was perceived.

E. Power Level Management as a Means of Ameliorating the Effects of Local-Area System Interference

Pinpoint has consistently maintained that wide-area, broadband AVM systems can co-exist with relatively low-powered local area systems (and Part 15 devices), whether broad- or narrowband. Central to any discussion of this issue is the essential difference between the communication ranges normally employed by the systems involved. Local-area systems, such as modulated back-scatter tag readers, operate over relatively short ranges, a few tens to a few hundred feet. (Part 15 devices operate over a few hundred to a few thousand feet.) By placing the wide-area systems base stations appropriately in relation, generally close, to low-power tag readers, and by appropriate choice of operating power levels, it is possible to reduce the areas in which unworkable interference to the forward link occurs to very manageable levels. As an example, see Figures 4 through 7. They illustrate the size of the signal "blackout" zones that a vehicular mobile of a wide-area system may experience near such a tag reader, for various separations between the base station and the reader station. As the base station moves closer to the local-area installation, the size of the black-out area shrinks rapidly.

Figures 8 - 11, respectively, illustrate the limits on communication range that the base station (mobile-to-base channel) experiences due to "jamming" of the mobile signal by the tag reader under the same conditions of separation as depicted in Figures 4 - 7.

Looking at all the figures together, we can see that the tradeoffs are: moving the base closer to the reader reduces the area of the "blackout" zone, but at the cost of reducing the mobile-to-base range for that base station. However, the mobile-to-base coverage of the network as a system can be managed by judicious placement of other network base stations sufficiently distant from the base station controlling the blackout zone around the interfering reader system. In this way, the areas over which the co-channel interference is "overwhelming" can be minimized dramatically, and certainly brought within bounds that can be considered "tolerable" to the wide-area system operation.[12]

Due to the close operational distances of the local area systems, and consequent high signal levels, the probability of interference to the local area system by the wide area base stations is very small to negligible. The signal levels at the tag reader due to a half-mile distant wide-area base station would only get up to between -40 and -60 dBm, yielding a large margin in the reader's performance. (The local-area reader typically uses a +30 dBm radiated level to produce a -10 dBm tag reflection measured at the reader.)

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[12] Additional receive-only sites could also ameliorate this situation.

The only circumstance in which the tag reader's margin will be overwhelmed is in the low-probability case of a vehicular wide-area mobile transmitting while in close proximity to the reader station. The probability is low because the mobile would probably be in the blackout zone and not be successfully "polled" by a base station.) Here the very low duty cycle and short duration of the mobile's signal will allow the tag reader to have at least a second opportunity at reading the tag.

F. Balance of Wide Area AVM Out- and In-bound Links on System Performance

The RF communication platform on which the ARRAY™ network is built uses a single, broadband, half-duplex link. As noted earlier, this link simultaneously carries both the messaging/protocol data and the time-ranging pulses within the same signal. The result is that no additional radio equipment, airtime or spectrum is required for the two principal functions of the system. System engineering analysis suggested to Pinpoint when designing ARRAY™ that operating the network in half-duplex mode was an important option. Making the link a single broadband half duplex channel allows a common set of the circuitry to perform much of the receive and transmit functions. This design feature produces a tremendous reduction in mobile transceiver complexity and in components. The net effect will be significant cost savings in the radios.

This should help explain why the ARRAY™ system's outbound (forward) link has such a wide bandwidth, a feature some may have found curious. The approach taken in the design of ARRAY™ was to find a single, economic solution that would provide all the radiolocation and bi-directional data communication functions compatible with high power in a single piece of equipment, and in a single wide-area network-function.

An examination of the typical message traffic patterns involved in the management of vehicles (summarized to some extent in Table 2) shows that the inbound (to the network) and outbound (to the mobiles) message volumes are significantly different, with the volume of outbound data being between two and ten times larger. A further examination of the requirements of a high-capacity radiolocating and data network operational protocols, shows that for radiolocation alone, the outbound link can consume a significant portion of the available airtime, unless the data rate of the outbound link is high.

One possible way to reduce a part of the outbound polling traffic is through an outbound link with very wide area coverage, as for example, in the "paging-style" forward link. Here a part of the polling overhead (*i.e.* the search for the cluster containing the unit being polled) could be smaller because a single outbound poll would reach the whole coverage area. However, the data capacity of such a (narrowband) paging link is small, and additional (narrowband) spectrum and communication channel equipment, are required. While the narrow bandwidth of the forward link would probably not limit seriously the performance of a radiolocation-only service, it would not offer an optimum or balanced communication solution for vehicle management.

Pinpoint's system approach verified that to minimize airtime a more balanced system, where about the same amount of airtime was being used for both the outbound and inbound links was needed. This required that the bandwidth of the outbound link needed to be similar to the bandwidth of the inbound (mainly radiolocation ranging) link. Hence, the Pinpoint solution: use the same technology for both links, and simplify the complexity (and lower the cost) of the mobile transceiver significantly.

G. Response to the Pickholtz Study

Professor Pickholtz's Engineering Analysis touches upon a number of facets of the design and performance of pulse-ranging radiolocations systems. There is much in his discussions concerning the nature and cost of time-sharing as a method for using the band for wide-area AVM/LMS operation with which we do not concur. Most importantly, he does not consider the single most important tradeoff that affects the performance of the Teletrac system, namely the consequences of designing a system to operate at too low a mobile power level to achieve a sufficiently high signal-to-noise ratio at the maximum design range to overcome the existing and future (e.g., AVM and Part 15 growth) interference in the band in which the system will operate.

It is clear from Teletrac's own submissions that its system was not crafted for the interference conditions present in the band and long made known in public record. (The original 1974 AVM Report and Order and the later 1989 Part 15 Report and Order spell out the kind of interference to be expected.) The fact that Teletrac's system may operate near a Cramér-Rao bound based on a hypothetical s/n ratio does not mean that its system performance in the 902-928 MHz band could not be dramatically improved. It only signifies that the designers did a good job of implementing their receiver and detector system under a certain set of presumed operating conditions. Choices of bandwidth, allowable path loss, and transmitter EIRP do effect the final s/n ratio used in determining the Cramér-Rao bound *for those choices*. Unfortunately, those assumptions do not necessarily coincide with the real-world operating environment at 902-928 MHz, which presents a wide range of possible interference. A wider examination of the actual operating conditions, including the fact that the interference levels the 902-928 MHz band are likely to reach the -80 dBm level due to growth in the numbers of local-area AVM systems, unlicensed Part 15 devices, and others, shows that the available communications ranges of a system operating at the Cramér-Rao bound based on unrealistic signal-to-noise expectations would be severely restricted.

Teletrac's own records confirm this. In Appendix 2 of Teletrac's comments, "Theoretical & Field Performance of RadioLocation Systems," Teletrac discusses field data measured on an operating Teletrac system in Dallas. The data at Page 13 of Teletrac's Appendix 2, on Figure 9, shows that a single 1 watt interferer near the center of its network reduces the number of base stations receiving mobile signals adequate for an acceptable position fix to 5. This is a similar power level to that which could be experienced from an innovative wide-area, Part 15, data reticulation network, such as those developed by companies like Metricom and others. Such networks intend to be widely deployed, utilizing hundreds of distributed, repeating transceivers. While Teletrac's own documents shows that it is likely that deployment of such a Part 15 system in Dallas would completely incapacitate the Teletrac system, Teletrac disingenuously suggests in their comments that they are "Part 15 friendly."[13]

The bottom line of this exploration is to show that one manageable way out of the co-channel sharing dilemma is through effective power management by the different users of the band, namely short range systems would use low power, and wide-area systems would use significantly larger power. Examples illustrating the workability of such power management have been

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[13] Note, however, that these data from the Teletrac field study also suggest that an increase in power of the mobile unit (which was operating at about -.5 dBw) would yield a significant improvement in the number of receive sites that detect the pulse.

given elsewhere in this Technical Appendix. In addition, Figure 9 of Teletrac's Appendix 2 demonstrates a marked increase in the number of receive sites that could be used for position fixing if its mobile units utilize only 10 dB more power. (They currently operate at an EIRP of about 1.25 watts depending on antenna choice.) Perhaps in retrospect, PacTel's choice to deploy a system using too little power to meet the link margin criteria for existing conditions was foolhardy -- even if it may have permitted designers to meet some arbitrarily low cost criterion.

As noted above, Pinpoint has advocated from the beginning of this proceeding that a practical alternative exists to exclusivity for existing licensees, which would effectively reserve the 902-928 band nationwide for only two operators of wide-area radiolocation systems (Teletrac and METS).[14] That approach is time-sharing.

In support of eliminating competing market entrants, Teletrac has hired consultants to critique the feasibility of this approach to efficient band sharing. Professor Pickholtz is far too eager to dismiss simple time slicing -- which is understandable when we consider who his client is. Let us focus on simple, fixed period, time slicing.[15]

We thereby sidestep all of the rhetoric about the difficulty of deciding what rules to use. We leave it to the successful

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[14] The currently issued licenses to these entities cover 80% of the United States population. The remaining markets are currently not viable to warrant the deployment of wideband, wide area systems. It seems that at some point in the past Teletrac may have thought that the band was going to be quieter than it has turned out to be. If one reads Teletrac's original license filings, one notes that the output power level of its mobiles was specified at a maximum of 158 watts ERP or about 21 dB above its actually implemented level of about 1.25 watts ERP. If Teletrac were now operating at that originally proposed signal level it would not be having nearly the problems of which it is now complaining. It seems that at some point between filing for its license and deploying its system, a decision was made to "go for a different target," and it turned out to be the wrong one. Now Teletrac is expecting the rest of the LMS industry to pay for its "mistake".

[15] Professor Pickholtz quickly dismisses several red herrings: Carrier Sense Multiple Access (CSMA); Token Passing; Code Division Multiple Access (CDMA). We agree with the Professor -- we don't believe these are the right approach. Therefore, we concentrate in these reply comments on the two simple means of orthogonally dividing a piece of bandwidth: fixed frequency division and fixed time division. We believe that there are time division scheduling approaches that are superior to fixed time slicing but we will not discuss them here -- *simple fixed time slicing is far superior to frequency division.*

licensees to determine if they want something better than fixed time slicing -- we merely insure that they have the opportunity to avail themselves of the enhanced performance those rules could deliver. We are even willing to forego the dynamic capacity sharing that more advanced forms of time division could deliver because there is no possibility of getting dynamic capacity sharing in a frequency division environment. **Fixed time slicing beats out frequency division -- possible gains from dynamic slicing are just gravy.**

This only leaves Professor Pickholtz's fears about the difficulty and overhead in implementing a time slicing function. He need not have worried -- Pinpoint has already implemented a workable solution. As detailed earlier, Pinpoint has built, and is operating experimentally the most advanced "non-military" radiolocation and mobile packet data system in existence. Pinpoint has conducted experiments to explore the complexity and cost of operating the systems stand-alone as well as time-sliced with another system on a 50-50 sharing basis with half-second-on, half-second-off timing. Pinpoint has also explored the complexity and cost of synchronizing the system with a reference signal, (e.g., GPS) such as would be used to coordinate the operation of multiple co-channel wide-area systems.

As explained above, synchronization overhead air-time "costs" are much less than one percent of capacity whether one is operating in a time-shared environment or standing alone. When